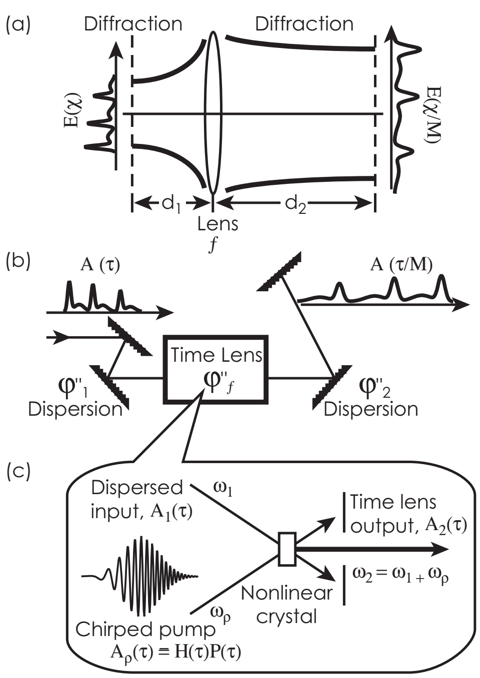
Ultrafast Transient Recording Enhancements for Optical Streak Cameras

Several experiments at LLNL will require hard x-ray and neutron diagnostics with temporal resolution of ~ 1 ps and a high dynamic range, particularly those experiments involving ignition. The Linac Coherent Light Source (LCLS) at the Stanford Linear Accelerator Center (SLAC) will need to measure timing and pulse shapes of its 100-fs fwhm x-ray pulse. These measurement requirements are far beyond existing capabilities.

This project will develop a "time-microscope" front end for optical streak cameras. It will magnify (temporally stretch) signals having ultrafast optical detail so they can be recorded with slower-speed streak cameras with a much higher fidelity. The system will be compatible with a new class of ultrafast radiation detectors that produce a modulated optical carrier in response to ionizing radiation.

Figure 1. Comparison of (a) spatial and (b) temporal imaging systems. A time lens (c) is produced by mixing the input signal with a chirped optical pump pulse.



Project Goals

Temporal imaging is based on a space-time duality between how a beam of light spreads due to diffraction as it propagates in space, and how pulses of light spread as they propagate through dispersive media, such as grating systems or optical fiber (Fig. 1). We have chosen to implement a "time lens" through sum-frequency generation of a broadband-chirped optical pump with the input signal in a nonlinear crystal, because of the improved resolution it produces.

We are developing a temporal imaging system using fiber optic technologies. The system will accept an optical signal at a 1550-nm wavelength that has ~ 600-ps duration and subpicosecond detail. It will have a temporal resolution < 300 fs, and will produce an output with 100 x temporal magnification, simultaneously shifting the signal to a 775-nm-center wavelength. The 300-fs input details, magnified to 30 ps at the output, will then be recorded with high fidelity on an optical streak camera.

Relevance to LLNL Mission

The success of NIF is critical to LLNL's stockpile stewardship mission. Our goal is to ensure delivery of the next-generation ultrafast diagnostics needed for critical experiments at NIF and other facilities, such as LCLS.

FY2005 Accomplishments and Results

Our laser's mode-locker driver and phase-locked-loop electronics were rebuilt to make the system compatible with NIF. The system now operates at the standard OC-12 rate (~ 622 MHz), the fourth harmonic of the OC-3 clock used by NIF. This guarantees that there would always be a time-lens pump pulse at any possible NIF trigger time. We have achieved the desired time-lens characteristics, including a 12-nm bandwidth, 53 ps/nm effective focal dispersion, 625-ps pulse width, and hundreds of nanojoule pump energy.

Significant ringing in the system's impulse response was predicted due to higher-order spectral phase aberrations in the input dispersion system. We have designed a correction for this distortion by combining multiple types of fiber with opposite aberration effects, canceling the net effect. The

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modeling of the initial design along with predicted results for the improved input dispersion design are presented in Fig. 2.

We have designed and implemented a time-lens mixing system that uses noncolinear sum-frequency mixing in 1 mm of periodically polled lithium niobate (PPLN). The pump and dispersed input signals are delivered via fibers, but the frequency mixing set-up is a bulk optic design in a fixed period PPLN crystal. An improved design using chirped-period PPLN waveguides is also being pursued.

Related References

1. Bennett, C. V., and B. H. Kolner, "Upconversion Time Microscope Demonstrating 103x Magnification of Femtosecond Waveforms," *Optics Letters*, **24**, 11, pp. 783-785, June 1, 1999.
2. Bennett, C. V., and B. H. Kolner, "Principles of Parametric Temporal Imaging-Part I: System Configurations," *IEEE J. Quantum Electronics*, **36**, 4, pp. 430-437, April 2000.
3. Bennett, C. V., and B. H. Kolner, "Principles of Parametric Temporal Imaging-Part II: System Performance," *IEEE J. Quantum Electronics*, **36**, 6, pp. 649-655, June 2000.
4. Bennett, C. V., and B. H. Kolner, "Aberrations in Temporal Imaging," *IEEE J. Quantum Electronics*, **37**, 1, pp. 20-32, January 2001.

FY2006 Proposed Work

We plan to optimize the current bulk-optic-based time-lens mixing crystal design and work on a chirped-PPLN waveguide design with much higher efficiency. We will add the output dispersion to the system, completing the temporal-imaging system. Output dispersion technologies will be investigated, but the leading candidate is chirped-fiber Bragg gratings. We will optimize and fully characterize the performance of the system.

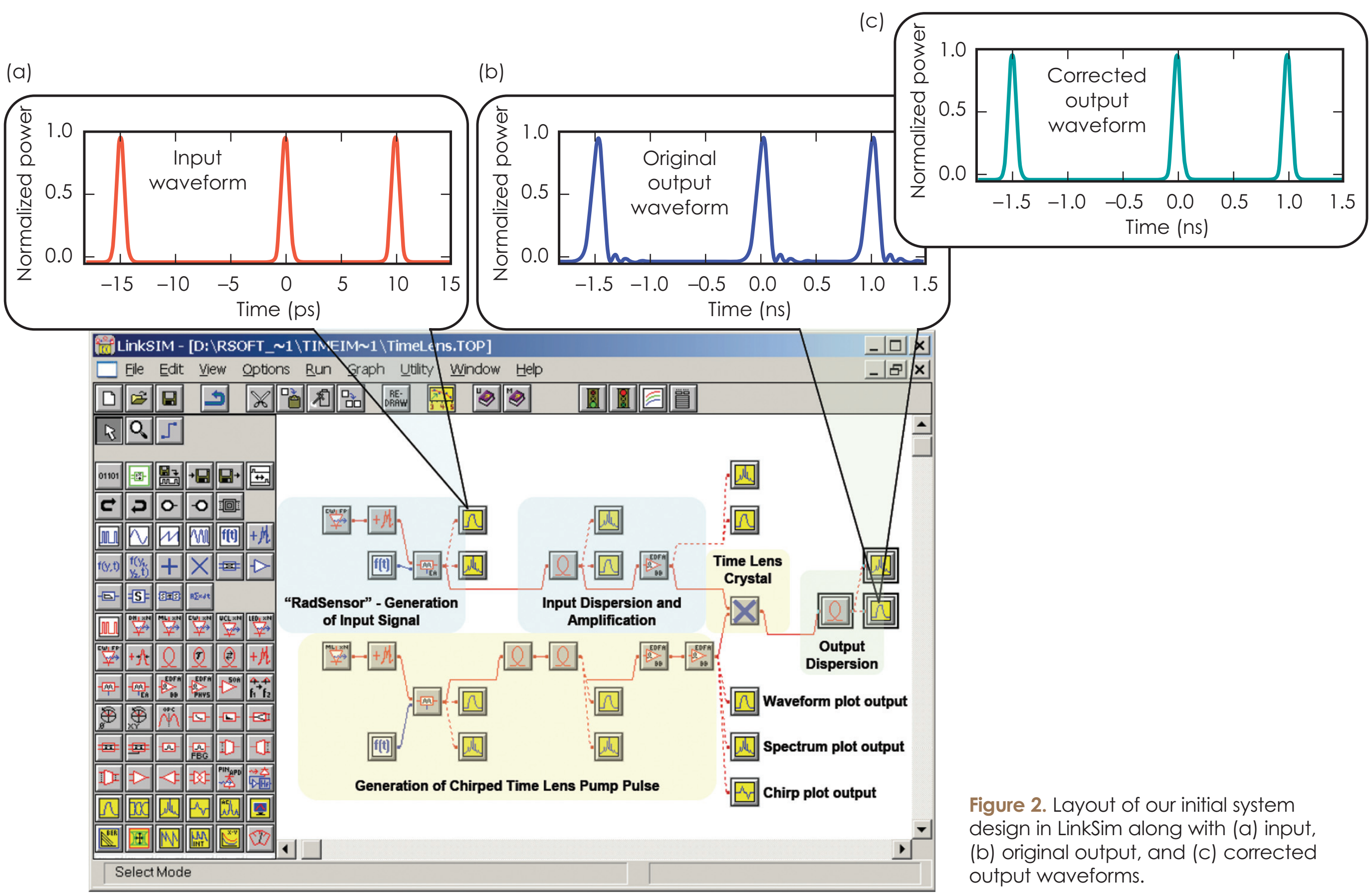

Figure 2. Layout of our initial system design in LinkSim along with (a) input, (b) original output, and (c) corrected output waveforms.